Space Weather Technical Forecast

Issued on Monday, 25 March 2024 at 01:07 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Further Minor/Moderate radio blackouts (R1/R2) expected. Current S1 conditions slowly reducing. Minor to Moderate geomagnetic storms (G1-G2) expected into Day 1 (25 Mar) given CME arrival 24th Mar and ongoing HSS, with a slight chance of Strong geomagnetic storm (G3) intervals at first on Day 1.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity recorded at GOES16 and 18 was Moderate, with AR3615 producing six distinct M-class flares through the period with the highest being an M2.7 at 24/0218UTC. There are now eight sunspots on the visible disc. AR3615 remains by far the largest and most complex group on the disc, showing top tier Fkc/Beta-Gamma-Delta complexity although perhaps some simplification and consolidation observed in recent hours. Changes in other groups were minor by comparison. Two new sunspot regions have appeared on the disc, a small alpha spot to the south of AR3615 and a new region which has rotated on the north eastern limb, this regions classification subject to change as it rotates further on to the visible disc.

No significant Earth-directed Coronal Mass Ejections (CMEs) observed on available coronagraph imagery over the last 24hr.

Solar Wind / Geomagnetic Activity: The solar wind at L1 measured by ACE and DSCOVR were initially at slightly elevated levels but steadily rose to elevated levels, 500-550km/s. A complex CME associated with the X1.1 flare on the 23rd March, which may have been two CMEs associated with the same event, then arrived at L1 at 24/1410UTC and solar winds jumped to strong-very strong speeds (750-850 km/s) where they have remained since. The solar wind density has largely been around or just above average, but became briefly well above average, early in the period likely as a result of a proceeding CIR region. Density then became below average for a time on entering the magnetic cloud associated with the CME from around 24/1830UTC. The IMF was initially weak to moderate but jumped to strong values from the CME arrival, briefly touching very strong (~33nT at 25/1606UTC). Bz initially weakly fluctuated -6/+6nT but became strongly negative from CME impact until 25/1548UTC, peaking at -26nT around 25/1510UTC from which point it has largely been strongly positive, especially since entering the magnetic cloud. The phi angle showed was largely negative (towards the Sun) but has become positive (Away from the sun) since entering the magnetic cloud.

The net result of the above solar wind measures was initially Unsettled to Active activity after a Moderate geomagnetic storm (Kp6) at 24/0000UTC. However from 24/1200UTC conditions returned to moderate geomagnetic storm (Kp6) following the CME arrival, peaking at severe geomagnetic storm (Kp8) from 24/1500UTC, falling to a strong storm (Kp7) at 24/1800UTC and Active (Kp4) from 24/2100UTC.

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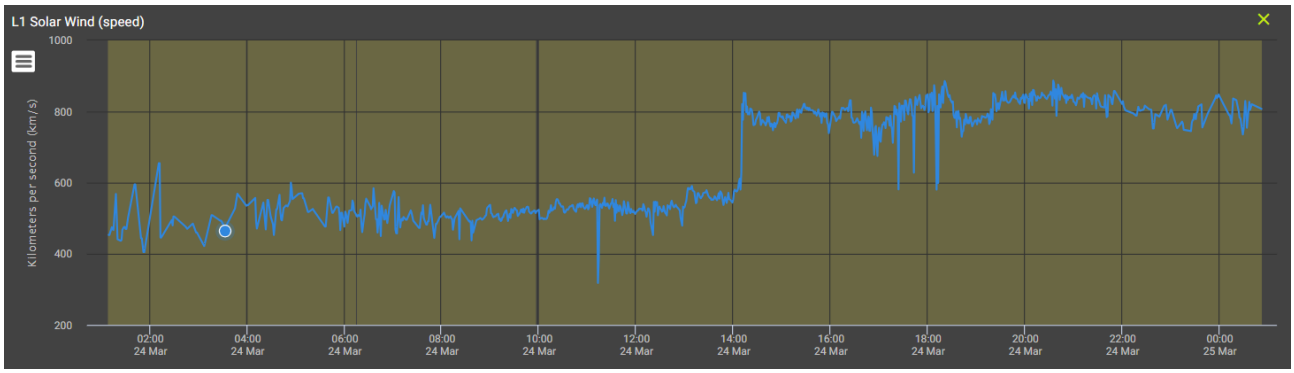
Figure 1: Solar wind at L1 as measured by ACE showing CME arrival at 24/1410UTC



Energetic Particles / Solar Radiation: GOES18 high energy (greater than 10MeV) proton flux was initially S2 levels with peak of 725pfu at 24/1235UTC, but fell to S1 levels from 22/2012UTC and have been on a slow but steady decline since.

High energy electron flux (greater than 2MeV) observed at GOES16 was at Normal Background levels. The observed 24-hour fluence was below the Active threshold, with a value at 25/0001UTC of 1.63e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Moderate to High activity is expected, with further M-class flares expected from primarily the highly active AR3615 through the forecast period, with a chance of isolated X-class flares.

Solar Wind / Geomagnetic Activity: A CME associated with the X1.1 flare on the 23rd March arrived at L1 at 24/1410UTC. Combined with a HSS associated with CH12/- is currently giving very strong solar wind speeds. There are no other earth directed CMEs in the forecast.

Wind speeds are expected to remain strong to very strong at first on Day 1 (25 Mar) but on a slow and steady decline over the coming days, however there is some uncertainty regarding this decline due to MOSWOC ENLIL underdoing speeds in association with CH12/- over the past 24 hours. Speeds are expected to reduce to background levels through Day 3 (27 Mar) and in the absence of further enhancements remain at background into Day 4 (28 Mar).

Initially geomagnetic activity is expected to give G1-G2 minor to moderate storm conditions to start Day 1 (25 Mar) with a chance of G3 strong geomagnetic storm (Kp7) intervals at first. These conditions expected to slowly ease, becoming Active-G1 by the start of Day 2 (26 Mar), continuing to ease through the day to become unsettled to active with perhaps a slight chance of residual G1 intervals. Through Day 3 (27 Mar) and into Day 4 (28 Mar) a return to generally Quiet to unsettled (Kp0-3) conditions is expected given likely waning of HSS influence and the absence of further CME enhancement.

Energetic Particles / Solar Radiation: High energy proton flux, as observed by GOES18 has recently reduced from S2 levels to S1 levels. A slow decline is now expected through Day 1 (25 Mar) in the absence of further significant flare activity, perhaps falling back to background levels by later day 2 into day 3 (26-27 Mar), although confidence is reasonably low given the number of different factors as well as the dominant AR3615 making continued progress westward through this four-day period to gradually increase the risk of further enhancement in association with significant flaring.

High energy electron flux (greater than 2MeV) is expected to persist at background levels at first, given the ongoing geomagnetic conditions associated with the HSS and recent CME impact. The associated 24-hour fluence is expected to persist below the Active threshold initially, but with an increasing likelihood of reaching Active fluence by the end of the period.

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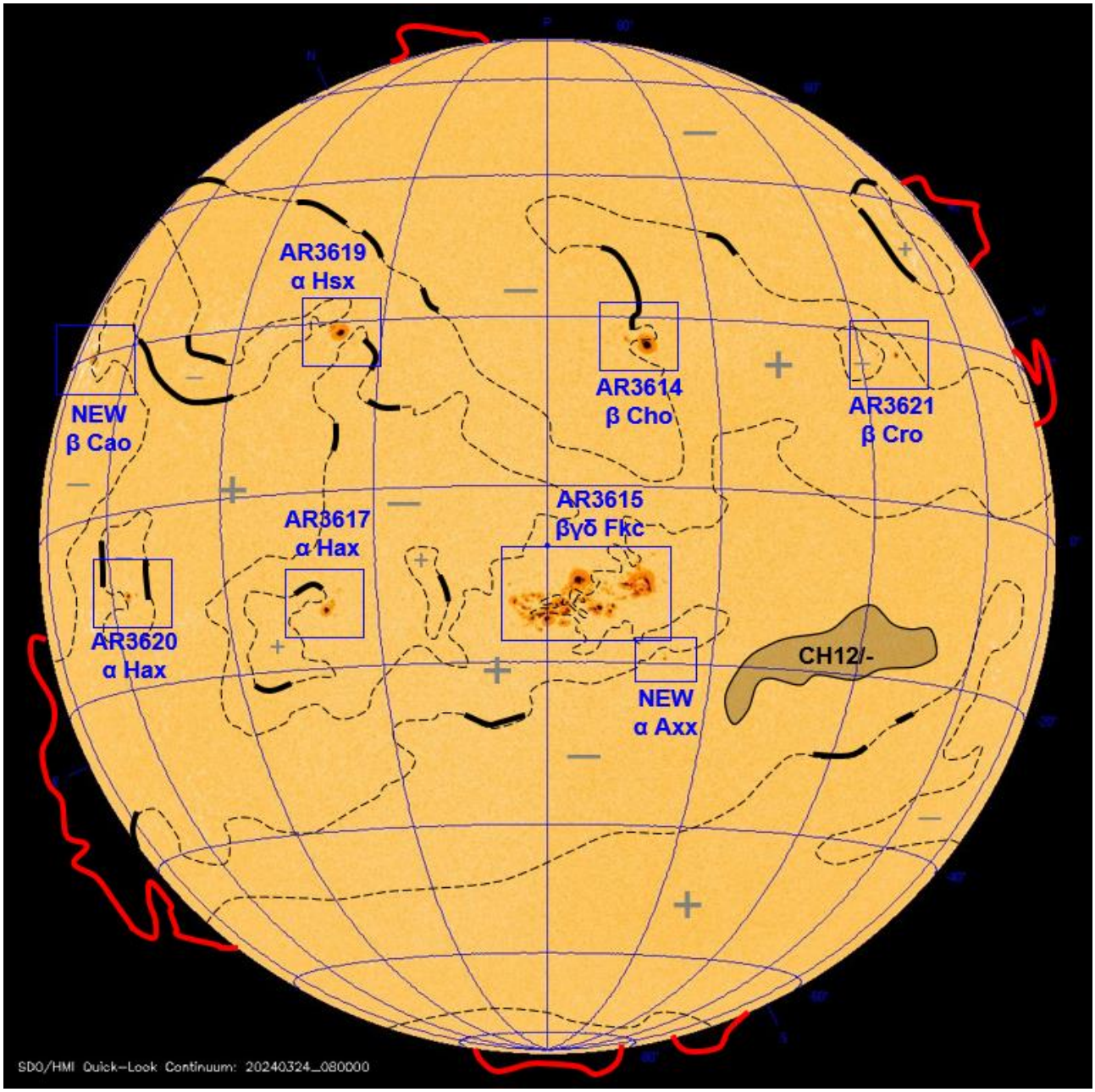
Figure 2: Solar Analysis Valid 24/2000UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

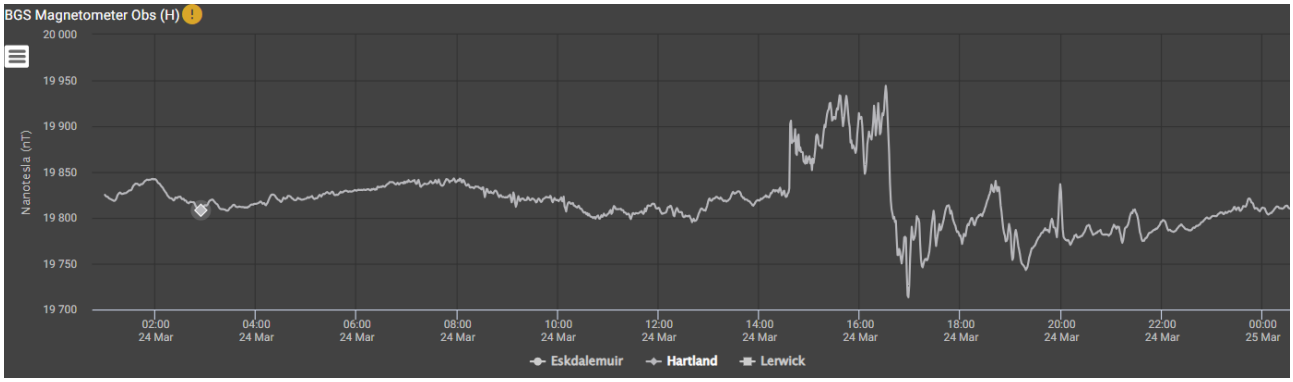
A CME associated with the X1.1 flare from a broad region north of AR3614 on the 23rd March, produced a complex halo CME which arrived at L1 at 24/1410UTC. The arrival of this CME combined with a HSS associated with CH12/- in the southeast of the disc is currently giving very strong solar wind speeds of around 800-850 km/s. There are no other earth-directed CME's in the forecast.

Wind speeds are likely to remain strong to very strong through the first half of Day 1 (25 Mar) but on a slow and steady decline as the impacts from the CME begin to wane. However due to MOSWOC ENLIL model historically predicting speeds associated with CH12/- poorly, there is some uncertainty regarding the reduction of the solar wind over the coming days. However speeds are expected to reduce back to background levels through Day 3 (27 Mar) and in the absence of any further enhancements remain at background levels through Day 4 (28 Mar).

Initially geomagnetic activity is expected to give G1-G2 (Kp5-6) minor to moderate storm conditions to start Day 1 (25 Mar) with a slight chance of G3 strong geomagnetic storm (Kp7) intervals at first as the influence of the CME likely continues. These conditions expected to slowly ease through the latter part of Day 1, becoming Active-G1 (Kp4-5) by the start of Day 2 (26 Mar) and continuing to ease through the day to become unsettled to active (Kp3-4) with perhaps a slight chance of residual G1 (Kp5) intervals. Through Day 3 (27 Mar) and into Day 4 (28 Mar) a return to generally Quiet to unsettled (Kp0-3) conditions is expected given likely waning of HSS influence and the absence of further CME enhancement.

Geo-Magnetic Storm	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Minor or Moderate	G1 to G2	Yes	70	20	5	5
Strong	G3	Yes	10	1	1	1
Severe	G4	Yes	1	1	1	1
Extreme	G5	No	1	1	1	1

Figure 3: Magnetogram showing magnetic field strength at Hartland and CME imact with earth at 24/1437UTC



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Radio Blackouts - X-Ray Flares:

The current Earth-facing disc is almost completely dominated in terms of flare activity by AR3615, with six distinct M-class flares through the period. This region continues to comprises a large number of spots although ongoing areal growth seems to be resulting in some consolidation. Significant mixing of its constituent magnetic polarities remains evident, particularly across the trailing portion, and the regions continues to display a Mt Wilson Beta-Gamma-Delta configuration, although once again perhaps signs of some simplification in recent hours. This region will continue to be closely monitored. The X1.1 flare on the 23rd was primarily associated with AR3614, which remains generally stable and much more magnetically simple, though it lies within a large plage region.

AR3615 (and AR3614) are expected to remain on the visible disk throughout the four days of the forecast period. No significant new sunspot regions are currently signalled to return onto the disk, however the as yet unnumbered region in the northeast does appear to be active with a full assessment of the regions yet to be made as it slowly rotates further into view. All considered, further M-class flare activity is expected through the period with the frequent flaring from AR3615 resulting in a high probability of activity. There is also a chance of isolated X-class activity primarily from this region, although for now regular energy discharge perhaps seems to be mitigating that risk somewhat.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	90	90	90	90
Very Active	R3 to R5 X Class	No	30	30	30	30

Figure 4: Latest 24hr GOES 16/18 X-ray flare trace and magnetogram image of AR3615.

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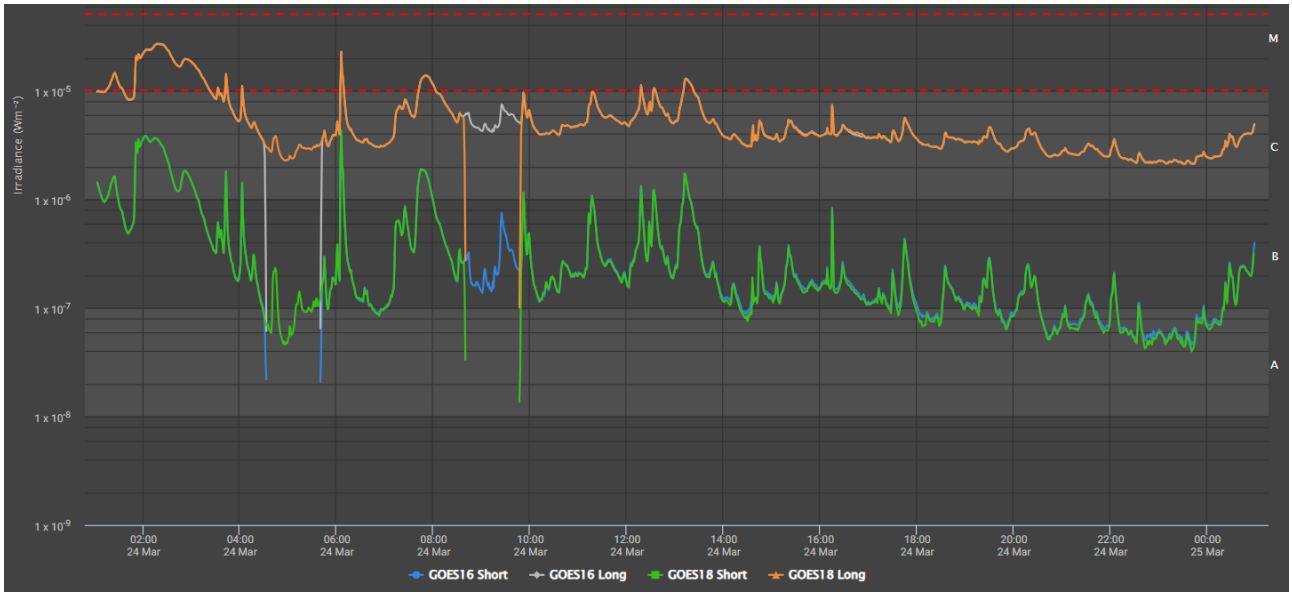

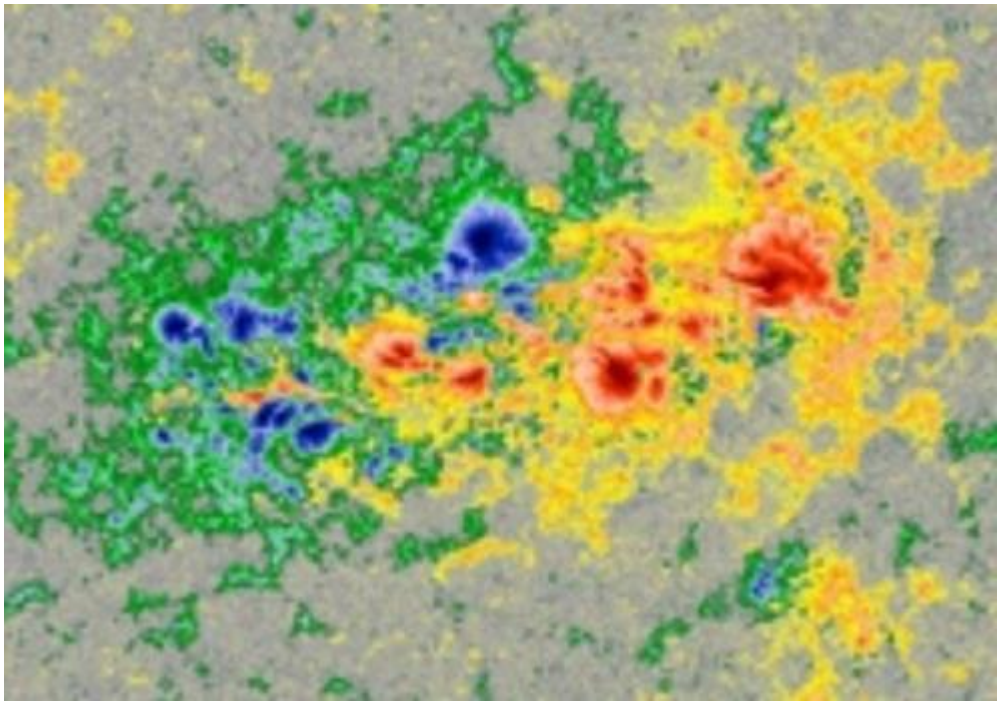

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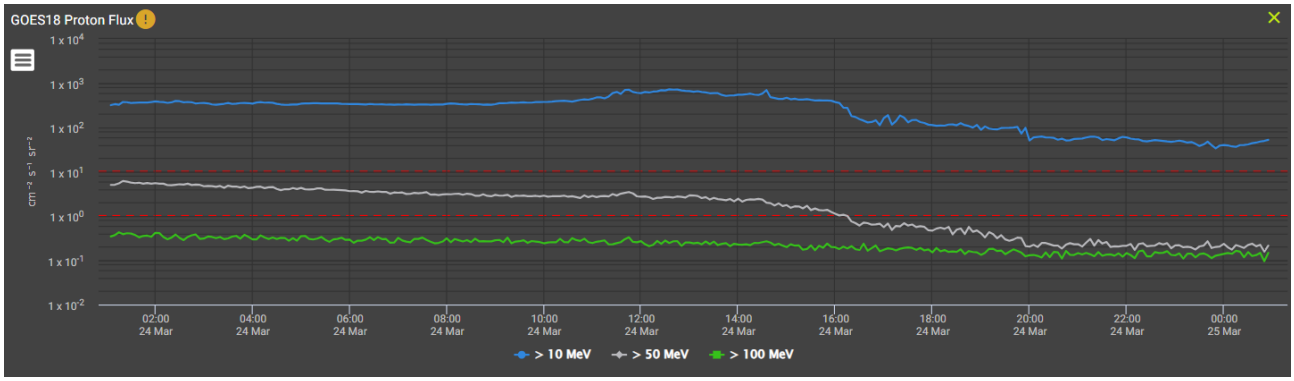
Solar Radiation Storms - (High Energy Protons):

High energy proton flux, as observed by GOES18 has recently reduced from S2 levels to S1 levels. A slow decline is now expected through Day 1 (25 Mar) in the absence of further significant flare activity, perhaps falling back to background levels by later day 2 into day 3 (26-27 Mar), although confidence is reasonably low given the number of different factors as well as the dominant AR3615 making continued progress westward through this four-day period to gradually increase the risk of further enhancement in association with significant flaring.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	Yes	100	70	40	30
Very Active	**≥ S3 ***	No	5	5	5	5
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 5: Latest 24hr GOES18 Proton Flux trace



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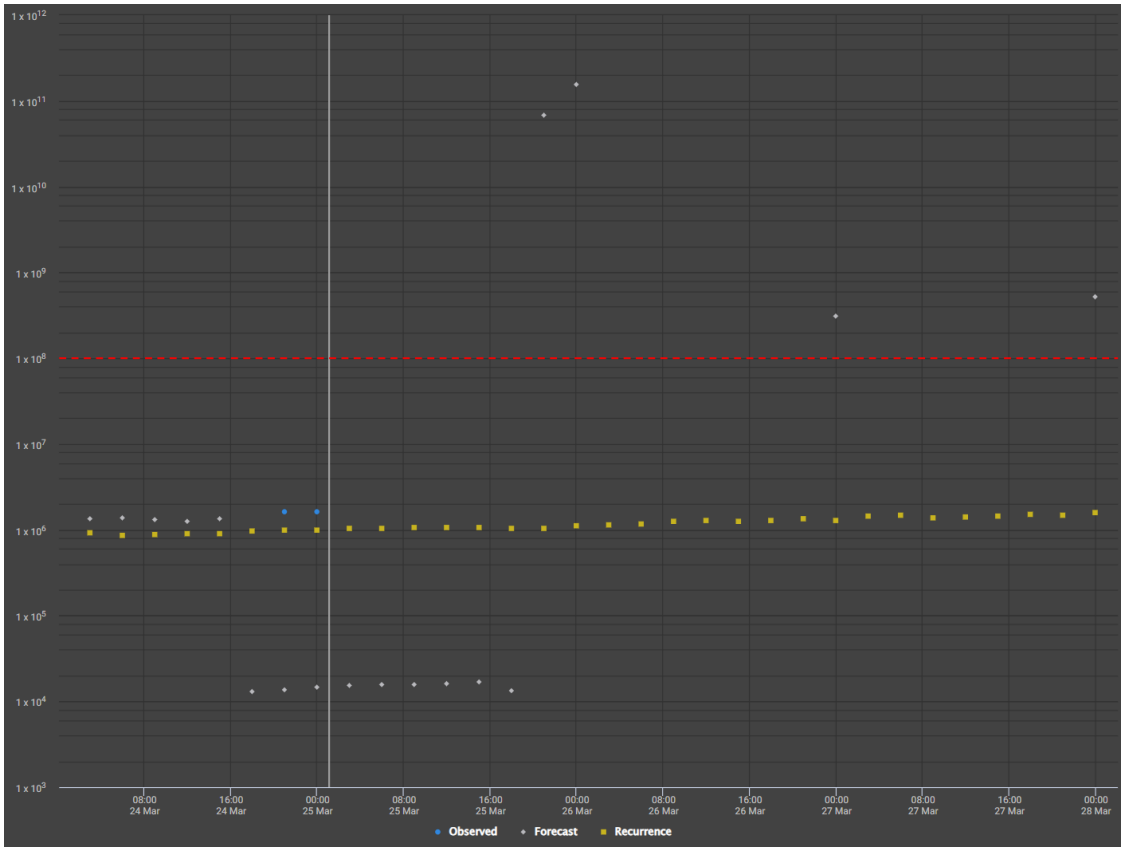
High Energy Electrons Event (≥ 2MeV):

GOES16 high energy electron flux is expected to remain at background levels initially giving ongoing geomagnetic response associated with the current connection to the HSS of CH12/- and recent CME arrival. Associated geomagnetic activity is expected to generally ease over the next few days, with the electron flux at GEO thought likely to see some rise to Moderate or High levels through the period.

The associated 24-hour fluence to expected to remain below the Active threshold initially, with MOSWOC REFM providing generally good guidance. Fluence is likely to rise into the new UTC week, with active fluence becoming increasingly likely by the end of the period. MOSWOC REFMs trend of showing increasing fluence over the next few days is accepted, although it is highly uncertain how fast the increase will take place.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	20	40	50	50
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	5	5	5

Figure 6: Latest MOSWOC REFM model output.



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